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21. LIFE HISTORY, EPHIPPIA DEVELOPMENT, CYCLOMORPHOSIS AND TEMPERATURE EFFECT ON LIFE CYCLE IN *DAPHNIA LUMHOLTZI* SARS (CLADOCERA: DAPHNIDAE)

(*With two plates & a text-figure*)

Introduction

Fish production in aquatic ecosystem depends largely upon the secondary link in the aquatic food chain, which constitutes important fish food organisms. Cladocerans are the main components of this phase of organic production which have nutritional values for the growth and production of fish. Although the importance of Cladocera as fish food, both for fry and adults, has been stressed by different workers (Alikunhi 1952, Pennak 1953, Hutchinson 1967, Kanaujia 1979), only scanty information is available on their seasonal abundance, life-cycle, cyclomorphosis and sexual reproduction in natural freshwater environment in tropical regions. In India, Michael (1962), Murugan (1973, 1975), Murugan & Sivaramakrishnan (1975, 1976), Navaneethakrishnan & Michael (1971), and Kanaujia (MS) have studied the life cycle, biology and seasonal abundance of various species of Cladocera. Observations made on the life-cycle, including effect of seasonal temperature, ephippial development and cyclomorphosis in *Daphnia lumholtzi* under laboratory and field conditions, and results obtained are presented in this paper.

Material and method

Daphnia lumholtzi collected from a fish pond at Cuttack, India (Long. 85°52′E, Lat. 20° 29′N) was used for the study. An egg-bearing female was reared separately in 1-litre beaker with the same pond water. Newly released young ones were reared individually in 20 beakers of 100 ml capacity filled with pond water filtered through No. 25 Nylobolt silk cloth. The filtered pond water contained minute nannoplankters. (*Chlorella* sp., *Scenedesmus* sp. and *Tetraspora* sp.) besides detritus, which served as food for the reared specimens. Water in the beakers was changed once every 24 hours. Observations were recorded on duration of each instar, length increment at each instar, total number of instars, number of young ones in each brood, total life span and water temperature.

For the study of different stages of embryonic development a hundred egg-bearing females were reared in a 10-litre glass jar. The developing embryo was dissected out of the brood sac and various stages were photomicrographed.

Another set of experiments was conducted

to study the influence of temperature on the life cycle.

Some possible studies were made on Cyclomorphosis and ephippial development through culturing the specimens in 10-litre glass jars filled with tap water and fed with cowdung solution (500 and 1000 ppm) and others with pond water.

Observations

D. lumholtzi thrive well on fine organic detritus as well as phytogroup of nannoplankton (*Scenedesmus* sp., *Chlorella* sp. and *Tetraspora* sp.) available in the pond. Their multiplication continued with the availability of required food. After a few days the density declined gradually and the pond water became

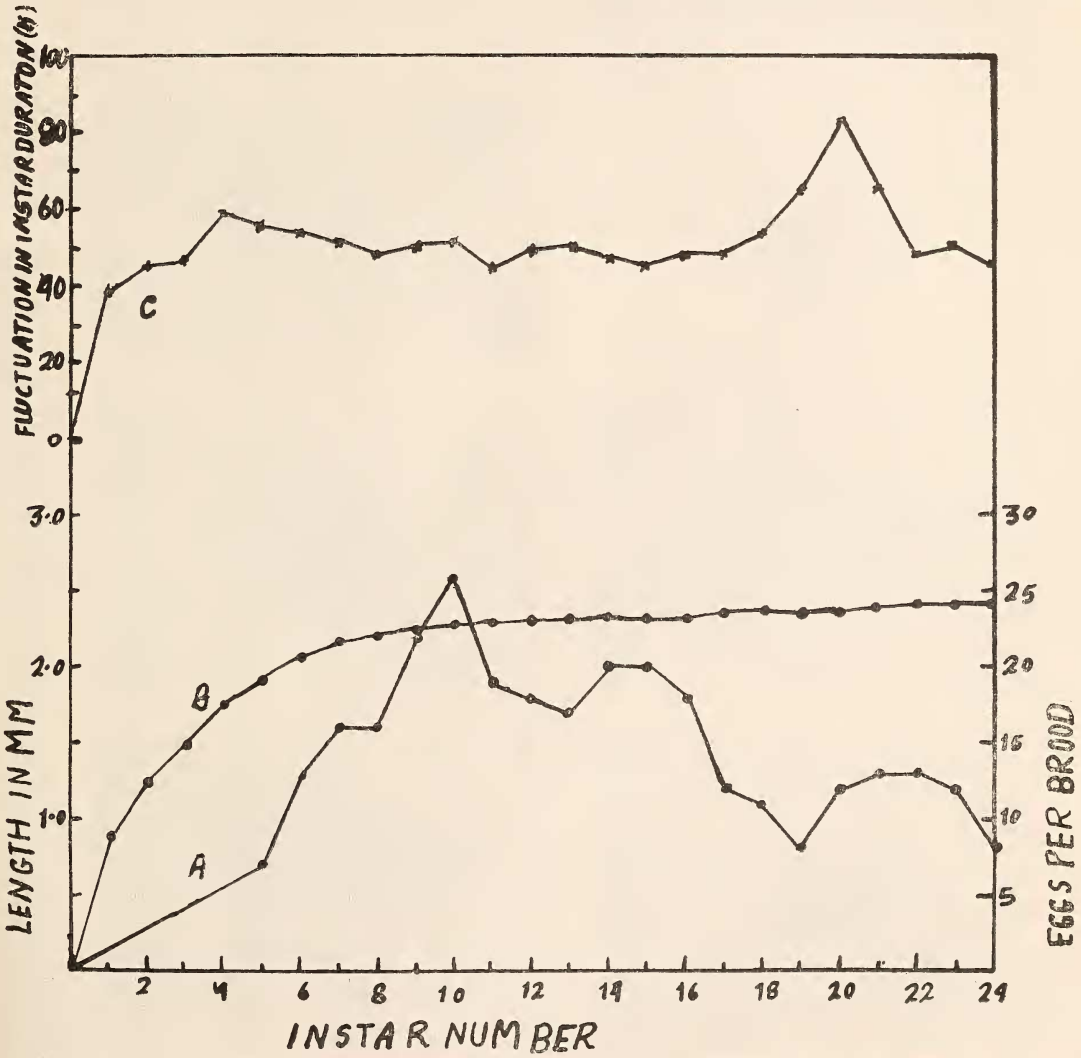


Fig. 1. (A) Instar number and eggs per brood, (B) Progressive growth increment at each instar, and (C) Fluctuation in instar duration in *Daphnia lumholtzi* at 18°-26°C.

clear from its original greenish colour. The same was observed in glass jars with tap water, cowdung solution and also water media containing *Tetraspora.*

Cyclomorphosis:

The specimens collected from the pond water at 16°-20°C water temperature had long anterior rostrum (0.73 mm) and posterior tail spine (0.76 mm) during December-February. When the same specimens were reared in jars, the rostral spine in most of the specimens atrophied and disappeared. In the newly hatched young reared in 100 ml beaker for the study of life-cycle the rostrum also got reduced after a few instars.

Life history:

The female laid eggs inside the brood pouch. Just after the last pre-adult instar, the newly released eggs assumed round shape. Subsequent development passed through eight embryonic stages as described by Green (1965) in the case of *Daphnia magna.* Liberation of young apparently preceded every moulting.

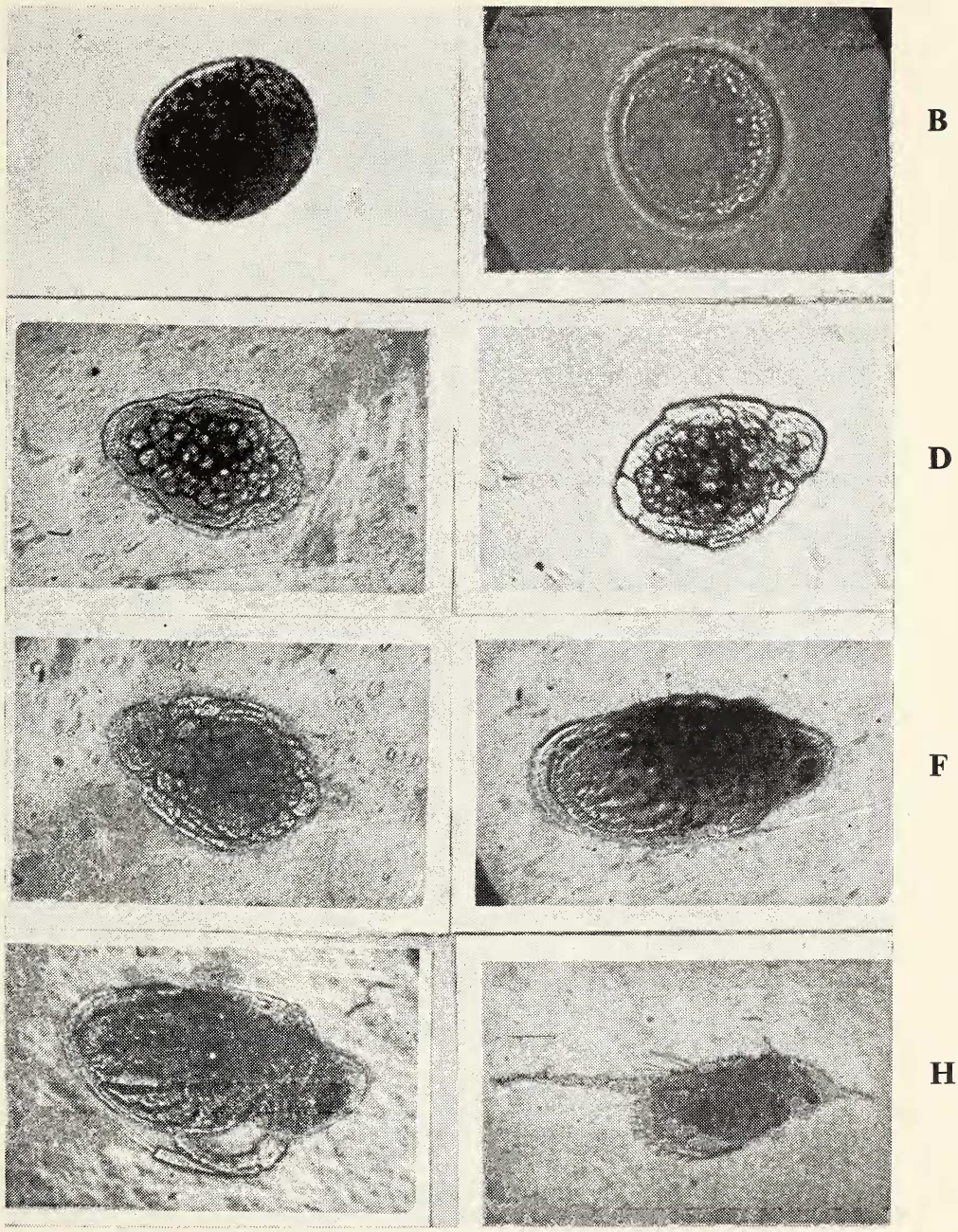
Various stages in the embryonic development of *D. lumholtzi* are as follows :

1. *Early stage*:
   a) *Early*: The egg spherical with translucent peripheral zone of green granulated cells (Plate I-A).
   b) *Late*: Central region of the egg shows yellow fat cells. Both the outer egg membrane as well as inner naupliar membrane (Plate I-B).
2. *Middle stage*:
   a) *Early*: Embryo well elongated anteroposteriorly surrounded by egg membrane (Plate I-C, D).
3. *Late stage*:
   a) *Early*: Distinct dark eyes formed; the cervical depression conspicuous (Plate I-E, F).
   b) *Late*: Embryos reach maximum length; paired eyes overlapping each other and finally fused; development of alimentary canal com-

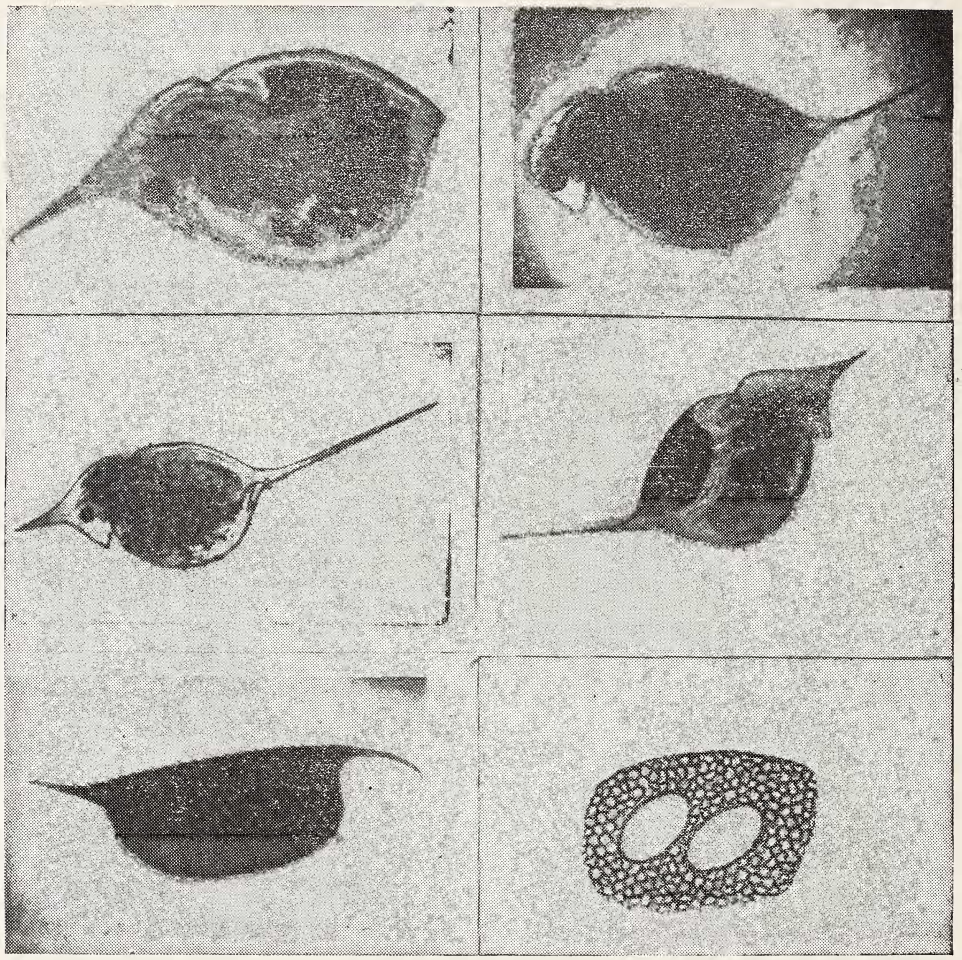
TABLE 1

MEAN LENGTH, NUMBER OF EGGS/BROOD, DURATION OF EACH INSTAR IN HOURS, CUMULATIVE DURATION OF EACH INSTAR IN HOURS AND CUMULATIVE FREQUENCY OF EGGS IN EACH INSTAR IN *D. lumholtzi* AT 18°-26°C.

Instar number	Mean length mm	Number of eggs produced	Total number of eggs produced	Duration of each instar (h)	Cumulative duration of each instar (h)
1	0.90	—	—	39	39
2	1.25	—	—	45	84
3	1.33	—	—	47	131
4	1.78	—	—	54	185
5	1.93	7	7	60	245
6	2.09	13	20	55	300
7	2.18	16	36	52	352
8	2.21	16	52	48	400
9	2.24	22	74	50	450
10	2.27	26	100	51	501
11	2.29	19	119	44	545
12	2.30	18	137	49	594
13	2.31	17	154	50	644
14	2.33	20	174	47	691
15	2.33	20	194	45	736
16	2.34	18	212	48	784
17	2.35	12	224	48	832
18	2.37	11	235	53	885
19	2.38	8	243	66	951
20	2.39	12	255	83	1034
21	2.40	13	268	65	1099
22	2.41	13	281	48	1147
23	2.41	12	293	50	1197
24	2.41	8	301	46	1243



A. Spherical egg with granulated cells (0.19 mm).
B. Spherical egg with the central circular area surrounded by granular cells (0.19 mm).
C. Elongated embryo with head rudiment, cleaved cells extending into the cephalic region (0.24 mm).
D. Embryo with head lobe and antennae (0.26 mm).
E. Elongated embryo with distinct head and limbs (0.76 mm).
F. & G. Late stage embryo with dark eyes and cervical depression (0.28 mm).
H. Newly hatched young one (0.76 mm).



A. Parthenogenetic female with eggs inside brood chamber and long rostrum but without tail spine — from pond water (2.61 mm).
B. Female with ephippia development, without rostrum from jar (0.94 mm).
C. Female with long rostrum and tail spine — from pond (2.28 mm).
D. Female with completely developed ephippia and long rostrum — from pond (2.44 mm).
E. Ephippium after moulting (1.15 mm).
F. Ephippial eggs with secondary inner membrane (hand sketch) (0.71 mm).

TABLE 2

COMPARATIVE DATA ON LIFE CYCLE OF 6 SPECIES OF CLADOCERA

Name of the species	*Daphnia lumholtzi*		*Cariodaphnia cornuta*		*Simocephalus acutirostratus*	*Daphnia carinata*	*Moina micrura*	*Scapholeberis kingi*
Temperature range	18°-26°C	24°-28°C	16°-25°C	18°-31°C	28°-30°C	28°-31°C	28°-30°C	28°-30°C
Number of pre-adult instars	4	3	2	2	4	5	2	2
Number of adult instars	20	18	17	25	18	8	11	17
Average eggs per brood	15.05	10.44	10.1	6.2	13.7	17.8	5.6	14.8
Range of eggs per brood	7–26	5–23	1–18	1–13	9–27	4–35	3–8	4–21
Total eggs produced	301	188	172.5	150.9	248	142.4	62.2	239.4
Average instar duration (h)	51.79	48.47	53.75	27.55	48.63	44.3	24	26.47
Range of instar duration (h)	39–83	24–76	37–71	20–34	27–72	–	24	24–38
Average duration of embryonic development (h)	52.51	50.38	53.75	29.83	46	40.8	24	24.0
Mean length (mm)	2.41	2.41	0.76	0.76	3.20	3.80	1.008	0.92
Cumulative duration of total instar (h)	1243	1018	1109.4	746	1071	576	312	493.6
Total life span (days)	54	44	46	31	44	24	13	20.5

pleted; appendages distinct; elongated pointed rostrum clearly seen (Plate I-F, G).

After complete development, the embryo hatches out from brood chamber resembling the adult in all respects (Plate I-H). The anterior rostrum in the newly hatched young one measured 0.19 mm and the characteristic tail spine 0.57 mm. The young one measured 0.76 mm excluding the two spines and reached adult stage after passing 3-4 pre-adult instar.

Ephippial development:

Ephippium in *D. lumholtzi* is observed in crowded populations after parthenogenetic breeding slows down. The postero-dorsal carapace becomes modified into a specially thick dark envelope in which the resting eggs lie and these become distinct from the rest of the exuvium to form the ephippium (Plate II-B, D, E). Its development starts with a small transparent patch which — increases in size, forming a honeycombed structure (Plate II-B). A pair of dark green elongated eggs could be seen clearly (Plate II-F).

After release of a pair of eggs by the female, a male *D. lumholtzi* which is smaller in size, was observed to get attached to the female, with its posterior part of the body. The honeycomb-shaped ephippium assumed white transparency initially and then turned brown to black (Plate II-E). It gets thickened and the

eggs were completely enclosed. The ephippium had two coverings in which the resting fertilized eggs lay — the outer one thick and black and the inner a translucent and thin membrane which could be taken out along with the paired eggs by gently pressing the ephippium (Plate II-F).

Effect of temperature:

Temperature was found to influence life cycle of *D. lumholtzi*. The instar duration (51.79 hrs), total number of eggs produced (301), average number of eggs per brood (15.05) and total life span (54 days) were found to be more at 18°-26°C as compared to the 24°-28°C (Table 2).

Discussion

Present study of life cycle of *D. lumholtzi* indicates that the animal passes through an average of 3-4 pre-adult instars, 20 adult instars and a total of 301 eggs are produced in a life span of 54 days at a water temperature of 18°-26°C which has shown close similarity with other daphnids (Table 2). Studies on pre-adult instars have been made by Michael (1962), Murugan (1975), and Murugan & Sivaramakrishnan (1976) in species which have two pre-adult instars and others with more than two pre-adult instars (Murugan & Sivaramakrishnan 1973, Navaneethakrishnan & Michael 1971, Anderson 1932, Anderson *et al.* 1937 and Anderson & Jenkins 1942). *D. lumholtzi* falls under the second group. It may appear that the smaller species which have two pre-adult instars mature earlier than the larger species, *C. cornuta*, *M. micrura* and *S. kingi* (Table 2).

D. lumholtzi has close similarity with other cladocerans — where the first adult instar has longer instar duration (63 hours) during which the females are premiparous, and duration of this adult instar is distinctly longer than the longest pre-adult instar (52 hours) (Table 1). However, this phenomenon was found almost to be different from the observations of Murugan & Sivaramakrishnan (1976) and Murugan (1975) where both the instars have similar duration (Table 2).

The progressive increase in size of the individuals at each instar was found to be rapid during pre-adult phase and gradual in the reproductive phase, indicating similar growth behaviour as studied in other cladocerans. However, Green (1956) reported that in many cladocerans the maximum growth was in early pre-adult instars. The rate of growth per instar is said to be correlated with the food supply (Hutchinson 1967).

The ephippial eggs in *D. lumholtzi* appear with crowding; specimens were observed with ephippium along with the parthenogenetic females with few eggs inside brood chamber. Lack of food indicated by the clarity of water appears to result in sexual reproduction. It is interesting to note that when the ephippial female was removed from a crowded population and kept in a beaker with sufficient food the ephippium was cast out along with the moult and the same female started developing eggs parthenogenetically. Pennak (1953), Banta & Wood (1939), Berg (1931), Brandt & Fernando (1971), Santharam *et al.* (1977) and Michael (1962) have reported that the ephippial development is influenced by the crowding of the mothers in a small amount of culture medium or by chilling the culture medium.

Cyclomorphosis is the seasonal polymorphism exhibited by successive generations of planktonic organisms throughout a year. *D. lumholtzi* indicated its prominent seasonal variations particularly in helmet. The long rostral spine (Plate II-A, C, D) while present in pond water